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BULLETIN

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OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAM

OF THE

BERKELEY MEETING

AT THE

UNIVERSITY OF CALIFORNIA

BERKELEY, CALIFORNIA

DECEMBER 18–19, 1931

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AMERICAN PHYSICAL SOCIETY

BERKELEY MEETING, DECEMBER 18–19, 1931

The 174th regular meeting of the American Physical Society will be held in Room 212 LeConte Hall, University of California, on Friday, December 18 and Saturday, December 19, 1931. The morning session of the Physical Society will begin at 10 o'clock on Friday and the afternoon session at 2 o'clock on the same day. The session on Saturday morning will begin at 10 o'clock and will be resumed at 2 o'clock if the number of papers warrants. Unless the sessions are forced to resume at 2 o'clock on Saturday, Saturday afternoon will be spent in tours of inspection of the Physics Department of the University of California for those members from out of town who wish to see the researches in progress in that laboratory.

Titles and abstracts of the papers to be presented at this session will be given in the following pages. These abstracts have not been corrected by the authors. After correction they will be published in an early number of the Physical Review. Authors should send all corrections to the Editor of the Physical Review at the University of Minnesota, Minneapolis, Minnesota.

Members will register on arrival in Room 101 LeConte Hall, where programs and other information are available.

Entertainment. Members of the Society will lunch together on Friday at 12:30 and on Saturday at 12:30, at a convenient restaurant at nominal cost. On Friday evening there will be an informal dinner for those members of the Society who care to attend, the place and time to be designated later. The cost will not exceed $1.50 a plate.

Accommodations. For those out-of-town members who wish hotel accommodations, Hotel Durant on the corner of Durant Avenue and Bowditch Street is available. This hotel is within 7 minutes walk of the Physics Building. The rates are: single rooms $2.00; with shower, $2.50; double room with shower, $3.50 (per day). Accommodations can also be had at the Hotel Claremont, about 1½ miles distant, and at the Hotel Whitecotton, ¾ mile from the Physics Building, on the corner of Shattuck Avenue and Allston Way. The rates for the Hotel Claremont are: $1.50 for single room; with bath, $2.00; and up (per day). Rates for the Hotel Whitecotton are: $1.50 for single room; with bath, $2.50; double room with bath, $3.50 (per day).

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Other meetings for the current season are as follows:

175. Annual Meeting. New Orleans. December 29–30, 1931.
176. February 25–27, 1932. Cambridge.
177. April 28–30, 1932. Washington.
178. June, 1932. Pacific Coast. Pullman, Washington.
179. June Meeting. New Haven. Time to be announced later.

LEONARD B. LOEB,
Local Secretary for the Pacific Coast

PROGRAM

FRIDAY MORNING AT 10 O'CLOCK

Room 212 LeConte Hall

1. The silvering of Fabry-Perot etalons by evaporation. H. E. WHITE AND S. S. BALLARD. *University of California.*—The method used is essentially that developed by R. Ritschl at the Physikalisch-Technische Reichsanstalt. The chief alteration from Ritschel's method is in the manner of vaporizing the silver. Here a method developed by Cartwright and Strong is employed. Instead of using a single filament of silver wire, a conical shaped molybdenum filament is used. Silver in the form of a small bead is placed inside the filament in contact with the molybdenum. Upon passing a sufficiently high current through the filament the silver is melted and brought almost to the boiling point where it vaporizes rapidly. With the etalon plates 15 cm from the filament two uniform films of the required thickness are obtained simultaneously in from one to five minutes. The pressure in the chamber is such that the mean free path is greater than the plate-filament distance. An optical pyrometer is used to determine the thickness of the silver film as it deposits, and the process is stopped when films of the desired transmission are obtained. This and the uniformity of the films obtained are the chief advantages over sputtering methods. In favorable cases etalons have been obtained where, with the filament of a 100 watt lamp as an object, 50 images at 6000A are seen with the eye. These etalons are being used in photographing hyperfine structure. In order to obtain resolving power in the ultraviolet, attempts will be made to adapt this method to the evaporation of platinum.

2. Photoelectric properties of thin films of rubidium and caesium on silver. JAMES J. BRADY, *University of California.*—By the use of a molecular beam a computed number of alkali metal atoms were deposited on a silver surface cooled with liquid air. The method was described by the author in a report (Phys. Rev. **37,** 230 (1931)) on the study of potassium films. The vapor pressures of rubidium and caesium for various temperatures were determined from data given in the International Critical Tables (Vol. 3, page 205). Spectral response curves were taken for various film thicknesses. The maximum threshold (approximately 6200A) in the case of rubidium was found to exist at a film thickness of 1.5 molecular layers (7.3×10^{14} atoms per cm^2). The maximum photoelectric emission occurred at a film thickness of 5.0 molecular layers and the photoelectric properties did not change when the film thickness was increased beyond 12 molecular layers. The threshold for the thick film was approximately 5900A. For caesium the maximum threshold, approximately 6600A, was found at a film thickness of 1.5 molecular layers (6.3×10^{14} atoms per cm^2). The maximum emission occurred at 5.4 molecular layers and the photoelectric properties remained constant for film thicknesses greater than 10 molecular layers. The threshold for the thick film was approximately 6300A. A theory is proposed which accounts for the existence of a maximum in the excursion of the long wave-length limit.

3. Monochromatic de Broglie waves of molecular beams. I. ESTERMANN, R. FRISCH AND O. STERN (Introduced by L. B. LOEB.), *University of Hamburg.*—An ordinary molecular beam of He which contains molecules of all velocities according to the Maxwell distribution law and con-

sequently a continuous spectrum of de Broglie waves, passed through a system of rotating toothed wheels. By this means monochromatic molecular beams containing only molecules of distinct ranges of velocities were produced. These beams were diffracted by the crossed-grating of the surface of a LiF crystal. The de Broglie wave-lengths of these beams calculated from the grating constant of the LiF crystal and the diffraction angles were in complete agreement (within a limit of 1 percent) with the wave-lengths calculated with de Broglie's equation $\lambda = h/mv$, v being determined from the dimensions and number of revolutions of the toothed wheels. The relative intensities of monochromatic beams of different wave-lengths were found to correspond to Maxwell's distribution law of velocities.

4. Absolute values for the mobilities of gaseous ions in pure gases. N. E. BRADBURY (Introduced by L. B. LOEB.), *University of California.*—With the method of Tyndall and Grindley adapted to a baked-out glass ionization chamber with an external source of intense x-ray ionization, the absolute values of the ionic mobility have been determined for several gases under conditions of high purity. Air was passed through a carefully constructed purifying train and liquid air traps. The absolute values of the mobilities found in this case were 1.60 and 2.21 for the positive and negative ion. Oxygen was prepared by fractionation of tank oxygen, by heating potassium permanganate, and by heating potassium chlorate. The first two of these methods gave 1.58 for the positive ion and 2.18 for the negative. The oxygen from potassium chlorate, however, showed an anomalous high mobility for the negative ion, values as high as 2.65 being obtained. The presence of chlorine oxides from the decomposing chlorate may be responsible for this. Nitrogen was obtained from a commercial tank and by heating sodium azide. The former method, even after passing the gas through the purifying train gave only 30 percent free electrons, a negative ion of mobility 2.21, and an abnormally high positive value of 1.82. Nitrogen from sodium azide gave no negative ions and 1.62 for the positive ion. Hydrogen was obtained from a commercial tank source, gave no negative ions, and showed a positive mobility of 8.25 with indications of the higher mobility ion observed by Loeb (Phys. Rev. **38,** 549 (1931)) with a mobility of 13.1. Helium, purified by passing through charcoal traps in liquid air gave on preliminary measurements a main mobility of 7.1 and an ion of high mobility 17.3 in agreement with values observed by Tyndall and Powell (Proc. Roy. Soc., **129,** 162 (1930)). No negative ions could be detected in the gas. Especially purified helium sparked over magnesium gave only the positive ion of mobility 17.

5. The collision cross-section of argon atoms for 300 to 2500 volt electrons. ROBERT B. BRODE. *University of California.*—A beam of electrons was defined by three slits set 90° apart on a circle 3 cm in radius. The first slit was 0.1 mm wide and the other two were 0.4 mm wide. The magnetic field of a large solenoid bent the electrons into this path and at the same time determined their velocity. The total cross-section of argon atoms that was effective in removing electrons from this beam was found by observing the decrease in current at the end of the path as a function of the gas pressure. When the current in the beam was over 10^{-7} amperes the current at the end of the path was not proportional to the current which started in the path. This variation was due to ionization along the beam and its effect was eliminated by using currents of 5×10^{-9} amperes. The curve of the cross-section plotted as a function of the velocity of the electrons decreases a little more rapidly than inversely proportional to the velocity. Small changes in slope appear at 24, 35, and 45 (volts)$^{1/2}$. The following table gives the values of q, the total collision cross-section in cm^2, and α, the absorption coefficient, which is the number of collisions per cm path at 1 mm pressure experienced by each electron.

(volts)$^{1/2}$	20	25	30	35	40	45	50
$10^{16}\times q$	2.98	2.17	1.69	1.24	1.01	.78	.65
α	10.7	7.80	6.08	4.45	3.62	2.84	2.35

6. Probable values of e, h, e/m and α. RAYMOND T. BIRGE, *University of California.*—The possibility of the simultaneous evaluation of e and h, from the totality of experiments designed to measure h, as discussed by Bond (Phil. Mag. **10,** 994, 1930 and **12,** 632, 1931) is of the utmost importance. This is potentially a far more reliable method for the evaluation of e than any direct determination. The writer, however, disagrees with Bond's selection of data, with some of his calculations and with all of his final results. In particular, Bond's calculated errors are

incorrect, due apparently to the use of least squares' formulas not applicable to the situation. The writer now presents a critical re-examination of available data, together with a discussion of the various squares' formulas required in this rather unusual type of calculation. The resulting values of e and h are found to depend chiefly upon the value adopted for e/m. With $e/m=1.761\times10^{7}$, which now seems well established, I obtain $e=(4.7721\pm0.0036)\times10^{-10}$, $h=(6.552\pm0.007)\times10^{-27}$, $1/\alpha=137.28\pm0.07$. This value of e is considered more reliable than any previous direct determination. If $1/\alpha$ equals 137 exactly (Eddington's theory), then e/m must equal 1.768×10^{7} approximately, and this value now seems quite improbable.

7. On the dependence of the length of the ultra-short electromagnetic waves upon the heating current of the tube and upon the amplitude of the oscillations. G. POTAPENKO, *California Institute of Technology.*—Previous work of the author has shown (Phys. Rev. **38**, 584, 1931), that a vacuum tube may generate oscillations, the frequency of which exceeds many times the frequency of electronic oscillations around the grid. Ultra-short "dwarf" waves of a few centimeters wave-length were obtained by means of this method. Experiments have shown that the frequency of "dwarf" waves are not exact multiples of the frequency of the electronic oscillations as might be expected. The theory proposed by P. S. Epstein shows that this discrepancy may be explained by the influence of the amplitude of the generated oscillations upon the movement of the electrons around the grid. Investigations of the dependence of the lengths of the generated waves upon the heating current of the tube and upon the amplitude of oscillations completely confirmed the prediction of this theory.

FRIDAY AFTERNOON AT 2 O'CLOCK

Room 212 LeConte Hall

8. The x-ray determination of the thermal expansion of Bi single crystals. A. GOETZ AND R. C. HERGENROTHER. *California Institute of Technology.*—The value of the thermal expansion coefficient parallel to the principal axis of Bi-crystals ($1/l_{\parallel}\cdot dl/dT=\alpha_{\parallel}$) has been determined by the measurement of the angles of Bragg reflections of the higher orders of Mo-Kα-radiation from the (111) plane, between room temperature and the melting point (272°C). The accuracy of this determination is of the same order as macroscopic measurements of expansion. The observations were made in order to compare the results with the macroscopic measurements of $\alpha_{\parallel}$ and $\alpha_{\perp}$ by Bridgman and Roberts. The decline of the macroscopic expansion 30°−40° before the melting point could *not* be found by x-rays proving that the crystal elements do not disintegrate before the point of fusion occurs. The values of $\alpha_{\parallel}/c_p$ (c_p=true specific heat) show furthermore a striking constancy over the range of temperature measured, whereas this ratio shows variations with temperature up to 100 percent for the macroscopic expansion. The difference between macroscopic and x-ray observations seem to indicate the existence of a secondary structure which begins to yield gradually before the melting point of the crystal element. Certain irregularities of the temperature dependence of the reflected intensities seem to strengthen this explanation. The mean value for $a_{\parallel}$ between 20° and 272° as obtained by x-rays is 16.1 $\times10^{-6}$ cm deg^{-1} which agrees with the macroscopic observation of Roberts (16.2×10^{-6}).

9. The momentum of a moving body in special relativity. W. V. HOUSTON, *California Institute of Technology.*—It is often difficult to visualize the nature of the added momentum given to a moving body by a uniform pressure acting on it. A simple picture of this effect may be constructed in the case of a perfect gas enclosed in a moving container. When viewed by an observer who is at rest with respect to the box, the molecules appear to be uniformly distributed among the different possible directions of motion. However, to an observer past whom the container is moving, more molecules are moving with the box than against it. This does not affect the total energy which is simply the scalar sum of the individual energies. It does, however, affect the momentum which is the vector sum of the individual momenta, and produces the extra term which involves the momenta.

10. Metamagnetism in Bi single crystals. A. B. FOCKE AND A. GOETZ, *California Institute of Technology.*—The influence of the presence of foreign atoms within the lattice of Bi crystals upon the magnetic susceptibility ($\chi_{\perp}$ and $\chi_{\parallel}$) is studied for the cases of Bi-Pb, Bi-Sn and

Bi-Ge. In all cases the foreign atom is enantiomorphic and thus cannot replace a Bi atom. As long as the concentration is below the solubility limit (0.5 to 5 percent) foreign atoms always cause an increase of the magnetic anisotropy as well as an increase of its temperature coefficient. Thus the normal anisotropy of pure Bi crystals ($\chi_\perp/\chi_\parallel=1.425$) (A. B. Focke, Phys. Rev. **36,** 319, 1930) can increase in case of a tin concentration at the solubility limit (*ca.* 3 percent) to values of 10^4. (A. Goetz and A. B. Focke, Phys. Rev. **38,** 1569, 1931.) At lower temperatures $\chi_\parallel$ decreases to zero and below $-3°$C the crystal is paramagnetic parallel to the axis and stays diamagnetic normal to it. Measurements of the quantitative effect of concentrations of foreign atoms (beginning at 0.005 percent Pb) yielded the following empirical formula for the inverse magnetic anisotropy of Bi:

$$\chi_\parallel/\chi_\perp=R=R_0-(\beta_0+\alpha_0\cdot N^\phi)\cdot(T_0-T)\cdots$$

where T=abs. temperature; T_0=temperature at which the influence of foreign atoms upon the anisotropy disappears; $R_0=R$ for $T=T_0$; β_0=temperature coefficient of R for purest Bi; N=concentration of foreign atoms; α_0=effect of one foreign atom upon R; $\phi=(N/\alpha)\cdot(d\alpha/dN)$. The values obtained for Bi are $T_0=813°\pm5°$ abs.; $R_0=0.95$; $\phi=0.5\pm0.005$. Hence α is the only constant which depends on the type of impurity. Pb and Sn follow the relation over the whole range of temperature, whereas Ge shows at high temperatures deviations which seem to indicate the formation of an intermetallic compound.

The influence of dissolved foreign atoms is too large to be accounted for in terms of a statistical volume distribution. It seems necessary to assume an adsorption in the internal surface of the crystal due to the boundaries of its secondary structure. Approximate calculations give the same value for the parameter of this structure (*ca.* 10^{-4} cm) as was previously observed. (Goetz, Proc. Nat. Acad. **16,** 99, 1930.)

11. Soft x-ray critical potentials of beryllium. R. J. CHRISTENSEN (Introduced by R. B. BRODE.), *University of California.*—Soft x-ray critical potentials up to 250 volts have been observed for freshly distilled Beryllium surfaces, observations being taken with the general type of tube employed by Richardson and his collaborators. When the photo current per unit bombarding current is plotted directly against the accelerating potential a number of points are discernable at which the slope of the curve abruptly changes. The considerably strongest break, occurring at 112.8 volts, is attributed to K radiation. In comparison the spectroscopic data of Söderman (Zeits. f. Physik **65,** 656) show for the K radiation a width of 12 volts, the short wave-length limit corresponding to 112 volts. The width is explainable by the broadening of the energy states for the atom within the metal. The value obtained by the critical potential method must correspond to an energy somewhat higher than the spectroscopic value, the reason being that the bombarding electron must possess sufficient energy to remove the K electron up to at least the lowest allowed energy state in the metal, which is probably among the upper Fermi states, and in addition retain sufficient energy to be in another, likewise allowed state; while the radiation emitted is for the most part due to transition into the K states from states of less energy than the higher Fermi states. Two other rather strong breaks occur at 9.3 and 11.7 volts. These may be ascribed to transitions from the Fermi group to possible discrete L levels. Other weaker break points are found at 18.7, 25.7, 33.7, 45.5 and 123.9 volts. A large number of very weak breaks of a rather unrepeatable nature are also observed.

12. Predissociation in the sulfur monoxide molecule. E. V. MARTIN AND F. A. JENKINS, *University of California.*—The ultraviolet SO bands, first described by Miss Lowater in 1906, and later studied by Johnson and Cameron and by Henri, have now been photographed in the second order of the 21-foot grating. Measurement and analysis of the rotational structure of five bands completely confirms their $^3\Sigma\rightarrow{}^3\Sigma$ character, and yields the following preliminary molecular constants: $\nu_e=39{,}362.6$, $\Delta G_v'=628.7-11.3(v'+\frac{1}{2})$, $\Delta G_v''=1124.97-12.287(v''+\frac{1}{2})$, $B_e'=0.501-0.006(v'+\frac{1}{2})$, $B_v''=0.7055-0.00505\ (v''+\frac{1}{2})$, $I_e'=55.21\times10^{-40}$ g·cm², $I_e''=39.21\times10^{-40}$, $r_e'=1.771\times10^{-8}$ cm, $r_e''=1.493\times10^{-8}$, $\gamma''\backsim0$, $\gamma'=\pm0.019$, $\epsilon'-\epsilon''=-0.686$. The spin tripling is completely resolved above $K'=30$, and can be studied to $K'=66$. Perturbations occur in the upper states, and are particularly strong for $v'=1$ and 2. A sudden breaking off of the rotational lines occurs for bands with $v'=0$ at $K'=66$, for $v'=1$ at $K'=52$, and for $v'=2$ at still lower K'. The $v'=3$ bands are very short, and no bands with higher v' are observed. This is readily explained as due to predissociation and leads to 5.10 ± 0.02 volts as the heat of dissocia-

tion of normal SO, in contrast to the value 6.41 obtained by Henri by linear extrapolation of the lower levels.

13. Mass ratio of the boron isotopes from the spectrum of BO. F. A. JENKINS AND ANDREW MCKELLAR, *University of California.*—Extensive measurements have been made of the α bands of BO as excited by active nitrogen. With the dispersion of the second order of a 21-foot grating, the data on the vibrational isotope effect permit a precise evaluation of the ratio of the reduced masses of $B^{11}O$ and $B^{10}O$, $\rho^2=\mu/\mu^i$. The vibrational term-differences were found by applying the accurate methods developed by Birge in his work on the masses of the oxygen isotopes. Using the (0,0), (0,1) and (0,2) bands, we obtain by least squares $\rho=\omega_e^i/\omega_e$ $=1.029071\pm0.000046$. Entirely independent data from the (1,0), (1,1) and (1,2) bands give $\rho=1.029087\pm0.000052$. The value of ρ corresponding to integral masses 11 and 10 is 1.029203. It is also found that the ratio of the band constants χ_e^i/χ_e equals ρ within the probable error, and that the requirement $\alpha^i/\alpha=\rho^3$ is satisfactorily fulfilled. Aston found the masses 11.0110 ±0.0016 and 10.0135 ± 0.0015 with the new mass-spectrograph, which gives the ratio B^{11}/B^{10} $=1.09962$, with a *limit* of error of ±0.00032. Our mean ρ corresponds to 1.09961, with a *probable* error of ±0.00006, for this ratio, assuming Aston's absolute value for B^{10}. This constitutes the first independent check on Aston's relative masses and shows them to be more accurate in this case than indicated by his limits of error.

14. Width of the D lines in sodium vapor. S. A. KORFF, National Research Fellow, *Mt. Wilson Observatory.*—Microphotometer contours of the *D* absorption lines of sodium vapor obtained with the 30 foot spectrograph at Mount Wilson show improved agreement with theory over values previously obtained. The lines are too wide, however, to have been produced by classical radiation damping. It is difficult to see, under the experimental conditions employed what other processes might be involved. The temperature range studied was from 180° to 300°C, representing vapor densities of approximately 10^{12} to 10^{14} atoms per cc. Above the latter temperature, pressure broadening sets in. The 2:1 ratio between the *D* lines is obtained, as is the theoretical variation of width with the square root of the number of atoms in the absorbing column.

SATURDAY MORNING AT 10 O'CLOCK
Room 212 LeConte Hall

15. New measurements of the 1, 1 Band of atmospheric oxygen. HAROLD D. BABCOCK AND WENDELL P. HOGE. *Mount Wilson Observatory.*—Previous measurements resulting in the discovery of the 1,1 band (Phys. Rev. **35**, 125, 1930) were made on a single plate. Eight new spectrograms, four from each of two excellent gratings, with solar zenith distances from 84° to 91° have now been measured. The increased air-path and improved photographic contrast permit measurement of 49 lines. These give within small errors of observation the same spacing of rotational levels of excited oxygen as we find from the *B* band, confirming Mulliken's interpretation of the atmospheric bands. The spacing of rotational levels of normal oxygen is systematically less for 1,1 than for *A*, *B*, and α bands, as would be expected. Taking separations of lines in P_1 and R_1 branches of 1,1 from homologous lines in the *B* band we find, after eliminating the rotational effect, that the first vibrational level of normal oxygen is 1556.393 ± 0.006 cm^{-1} above the ground state. A small error is found in the earlier determination of this interval and allowance for this makes that value consistent with the new, more reliable result. The second doublet in the tail of 1,1 is closely matched in intensity by the eighteenth in the tail of 0,0.

16. Variation with temperature of the continuous absorption of light by diatomic gases. G. E. GIBSON. *University of California.*—Condon has shown that the continuous absorption arising from molecules in the lowest vibrational state ($v''=0$) should vary with frequency in the manner actually observed; the maximum in the vibrational wave function, giving rise to a maximum in the absorption coefficient. Extending his reasoning we should expect the absorption arising from molecules in the first vibrational state ($v'=1$) to give two maxima corresponding to the maximum and the minimum of the wave function. Corresponding to the single node of the wave function ($v''=1$) we should have zero absorption near the frequency for which the absorption from $v''=0$ is a maximum. This is qualitatively in accord with measurements by

Bayliss on chlorine (not yet published). Near the maximum the absorption diminishes with temperature, owing to the decreasing number of molecules in the lowest vibrational state, while at frequencies farther from the maximum the increasing number of molecules in the first vibrational state causes the absorption to rise with temperature.

17. A double crystal x-ray spectrometer and spectrograph. P. A. Ross. *Stanford University.*—A double crystal spectrometer has been built which seems to possess certain advantages in convenience of operation. The first crystal does not rotate but is moved along milled ways perpendicular to the mid-point of the line joining the focal spot to the axis of rotation of the second crystal. The beam reflected by the first crystal always passes over the axis of rotation of the second crystal which is mounted on the table of a large Bragg spectrometer equipped with a fine slow motion reading in seconds of arc. Both crystals and their fine adjustment controls are mounted on easily removable plates. Two taper pins in each plate provide for the accurate replacement of either crystal in its original position or turned through exactly 180°. The constants of the apparatus having been determined, the crystals may be removed and replaced, used in parallel or anti-parallel position, or as a single crystal spectrometer with no loss of time hunting for lines. By means of an electric rocking device, the apparatus has been used as a double crystal spectrograph showing the β doublet resolved and the γ and δ lines in molybdenum.

18. The effect of transverse magnetic fields on the thermal conductivity of bismuth at low temperatures. E. J. Knapp. *University of Wisconsin.*—A vacuum conductivity method was employed to observe the thermal conductivity of polycrystalline bismuth in transverse magnetic fields ranging from zero to 11,000 gausses. Two series of observations were made. In the first series the average temperature of the specimen was −160°C; in the second series it was −119°C. The variation of the relative decrease in thermal conductivity with magnetic field strength was found to fit the equation, $\Delta\kappa/\kappa = BH^2/(1+CH^2)$. The maximum decrease was 28.9 percent in the first series of observations and 24.0 percent in the second series. In the first series the point of inflection of the curve, $\Delta\kappa/\kappa$ against H, appeared at about one-ninth of the maximum field strength; in the second series it appeared at about one-fifth of the maximum field strength. This work is being extended to single crystals at the University of Wisconsin.

19. The spectra of two-and-three-valence-electron atoms. Si_{II}, P_{III}, S_{IV}, Si_{III}, P_{IV} and S_V. I. S. Bowen, *California Institute of Technology.*—New measurements of the vacuum spark spectra of silicon, phosphorus and sulphur have been made with a vacuum spectrograph. With the aid of these data it has been possible to analyse a large number of hitherto unclassified lines as follows; in Si_{II}, P_{III} and S_{IV} many of the important quartet lines have been located. In Si_{III} and P_{IV} the stronger singlet lines have been classified, while in these ions and in S_V a large number of lines involving terms in which both electrons are excited have been identified.

20. Thermal expansion of copper alloys. Peter Hidnert. *Bureau of Standards.*—The linear thermal expansion of two cast copper alloys was investigated. One alloy (sample 1444A) made by the Bunting Brass and Bronze Company contained copper 84.84, tin 14.95 and lead 0.21 percent and the other alloy (sample 1445) prepared at the Bureau of Standards contained copper 85.0, tin 5.0, zinc 5.1 and lead 4.9 percent. C. E. Eggenschwiler and H. B. Gardner determined the chemical composition of the first and second alloy, respectively. The following coefficients of expansion were obtained from the observations on heating.

Temperature range	Average coefficients of expansion per degree centigrade	
	Sample 1444A	Sample 1445
20 to 100°C	18.0×10^{-6}	17.8×10^{-6}
20 to 200	18.2	18.1
20 to 300	18.6	18.5
20 to 400	18.8	18.9
20 to 500	19.3	19.3
20 to 600	19.8	20.0
20 to 700	—	20.6

The results indicate that the substitution of about 5 percent zinc and 5 percent lead for 10 percent tin in the first alloy, caused slight if any changes in the coefficients of expansion.

SUPPLEMENTARY PROGRAM

21. Theory of the continuous absorption of light by diatomic molecules. G. E. GIBSON AND O. K. RICE, *University of California and Harvard University.*—The theory of the effect described in Abstract 20 has been developed on the basis of quantum mechanics, and is found to be in quantitative agreement with the observed absorption curves and temperature coefficients.

22. On the measurement of the energy of ultra-short electromagnetic waves. G. POTAPENKO, *California Institute of Technology.*—Because of the lack of methods for direct absolute measurement of the energy of ultra-short electromagnetic waves, the author proposes an approximate method of measuring the energy. This method is based on the determination of the amplitude of oscillations and of the current which appears in the plate circuit of the tube generating ultra-short waves. In this way the energy of "dwarf" waves (see previous abstract) has been measured and a method of increasing their energy by means of negative plate potential has been studied. The power of ultra-short waves generated with *one* amplifier tube can in this manner be brought up to 0.08 watts for wave-lengths of about 10 cm and up to 0.2 watts for wave-lengths of about 60 cm.

23. The calculation of errors by the method of least squares. RAYMOND T. BIRGE, *University of California.*—The assumption underlying the various least squares' formulas for the calculation of errors are stated, and the true meaning and applicability of the formulas are critically discussed. New experimental data are presented which indicate the essential correctness of the Gaussian error curve, in the region of large residuals as well as small. Scarborough's deduction (Proc. Nat. Acad. Sci. **15**, 665, 1929) that the calculation of errors from *internal* consistency is correct, but the calculation from *external* consistency is invalid, is shown to be entirely unjustified. Either method may be used, if only accidental errors are involved, and any serious disagreement of the two methods is a sure indication of the presence of constant or systematic errors. In this latter situation the error calculated from internal consistency is obviously untrustworthy, yet the literature abounds in examples of the use of such false errors,—notably in F. W. Clarke's extensive calculations of atomic weights. In this situation the only feasible procedure is to assign weights arbitrarily and calculate the error of the resulting weighted average by means of *external* consistency. The above conclusions are illustrated in detail, using actual observational data.

24. Nuclear spin of phosphorous from the band spectrum. F. A. JENKINS AND MURIEL ASHLEY, *University of California.*—The resonance band system of the P_2 molecule, first measured by Geuter, and recently studied by Herzberg and by Jakolewa (Zeits. f. Physik **69**, 548, 1931) has been photographed in emission with high dispersion. The rotational structure is well resolved in the region 2300–3300A, but overlapping is serious except for a few bands between 2700–3000. These show only P and R branches consisting of single lines, the structure characteristic of a $^1\Sigma \rightarrow {}^1\Sigma$ transition. Alternating intensities occur in each branch, and are particularly well marked in the band at λ2953.9, for which the P and R branches are approximately superimposed. This is the 6,22 band, according to Jakolewa's assignment of vibrational quantum numbers. A number of the neighboring bands have the two branches separated, and the alternation of intensities in each is definite. The alternation ratio observed visually appears to be 3:1, giving for the nuclear spin $I = \frac{1}{2}$. Until quantitative measurements are made, the ratio 2:1 cannot be definitely ruled out, although not expected theoretically for atoms containing an odd number of nuclear protons. A detailed analysis of the rotational structure of this band system is being undertaken.